Topics for Today:

- **Announcements**
  - Office hrs: 4:05pm-4:55pm Mon, Wed; 10-11am Fri (SB27)
  - Office: EERC 614. Phone: 906.487.2857
  - XFMR exercises due next Mon 9am.
  - Recommended problems from Ch.2, solutions posted

- **XFMR, Chapter 2 - Transformers and circuits w/transformers**
  - Pre-Req Videos 3-6 - View them, study notes!
  - Single phase ideal transformer is building block - V, I, dot convention!
  - 3-phase transformer banks and phase shifts (ANSI/IEEE vs. IEC)
  - Standard 30° shift transformers, non-standard connections
  - Pos/neg sequence phase shifts, sequence networks.
  - Autotransformers
  - Load Tap Changing (LTC) transformers
  - Phase shifting transformers
  - Paralleling transformers with a) unlike impedances; b) unlike tap positions
  - Three-winding transformers
SEQUENCE NETWORKS
FOR TRANSFORMERS
Per Phase Equiv:

- \( V_{AN} \)
- \( L-N \) per phase equiv
- Per Unit Values:
  - \( V \)
  - \( I \)
  - \( Z \)
  - \( Y \)
  - \( P \)
  - \( Q \)
  - \( S \)
TRAP: Text books have "cook-book" egns assuming that all transformers are std. 30°. WRONG!

MANY OTHER OPTIONS
±30°, ±90°, ±150°  Δ-Y  Y-Δ
Ao open \( \Delta X \) \( \oplus \) \( \Delta \) is ungrounded.

open? (if \( \Delta \) is open)

Zero Ref.
$I_{AO}$

$V_{DROP} = 3I_{AO}Z_N = V_{NG}$
- Protection
- Aux Power (Station Service)
- Zero-seq Circ Path

Delta: - trip triplen harmonics
- Buried Delta
- Buried tertiary
- Triplen harmonics
Zero ref.

Harmonics:
3, 6, 9... =
1, 4, 7... =
2, 5, 8... =

↑ xfrm in rsh
**Factory Test Report**

- S.C. Impedance (VR, S.C. Studies)
- Loss Evaluations
  - No-load losses (core) $Re$
  - Load losses $R_1 + R_2x^2$

\[ \frac{V^2}{Re} \]

\[ I^2R \]

\[ R_1 \text{ and } jX_1 \]

\[ R_c \text{ and } jX_M \]

\[ R_c + \frac{jX_M}{3} \]
Binary S.C. Tests

<table>
<thead>
<tr>
<th></th>
<th>MVA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P-S</td>
<td>300</td>
<td>15.95%</td>
</tr>
<tr>
<td>P-T</td>
<td>100</td>
<td>8.70%</td>
</tr>
<tr>
<td>S-T</td>
<td>100</td>
<td>2.61%</td>
</tr>
</tbody>
</table>

Reactance

\[
\begin{align*}
\text{P} & : jX_P \\
\text{S} & : jX_S \\
\text{T} & : jX_T
\end{align*}
\]

"Star Egniv" for 100 MVA System Base
Convert to 100 MVA Base

\[
\begin{align*}
Z_{pu} &= \frac{Z_n}{Z_{BASE}} = \frac{Z_n}{V_{BASE}^2} \\
Z_n &= Z_{pu} \times Z_{BASE, old} \\
Z_{pu, 100} &= \frac{Z_n}{Z_{BASE, new}} = \frac{Z_n}{100} = \frac{Z_n}{420^2} \\
Z_{BASE} &= \frac{420^2}{100}
\end{align*}
\]
\[ \tilde{Z}_{PS} = \tilde{Z}_P + \tilde{Z}_S \]

\[ \tilde{Z}_{PT} = \tilde{Z}_P + \tilde{Z}_T \]

\[ \tilde{Z}_{ST} = \tilde{Z}_S + \tilde{Z}_T \]

Solve for \( \tilde{Z}_P, \tilde{Z}_S, \tilde{Z}_T \)

Transforming for \( Y \rightarrow \Delta \)

\[ P \rightarrow S \]

\[ \tilde{Z}_P, \tilde{Z}_S, \tilde{Z}_T \]

\[ EE \ 5240 \]
APPENDIX C: TRANSFORMER FACTORY TEST REPORT

TRANSFORMER TEST REPORT

Date of Test: 6/3/72  Customer's Order: C-67899  Our Order: C-01070-5

Type: 3F01/3F0A  Phase: 3  Cycles: 60  Rise 55°/65°  Tape 30°/255°  Spec: 13218

H. V. Volts 315000  L. V. Volts 118000  T.V. Volts 132000

KVA 225000/291000/420000  KVA 225000/291000/420000  KVA 77000/102667/128333

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>C-01070-5-1</th>
<th>Guarantee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarity &amp; Tap</td>
<td>#327555</td>
<td>Transformer Core 115000/115000 386 MVA</td>
</tr>
<tr>
<td>W.T. Copper Loss 100% Voltage</td>
<td>78.73</td>
<td>312000</td>
</tr>
<tr>
<td>Core Loss 100% Voltage</td>
<td>286500</td>
<td>312000</td>
</tr>
<tr>
<td>Total Loss 100% Voltage</td>
<td>676500</td>
<td>312000</td>
</tr>
<tr>
<td>Core Loss 110% Voltage</td>
<td>342900</td>
<td>392000</td>
</tr>
<tr>
<td>% Exciting Current 110% Voltage</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>% Exciting Current 100% Voltage</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>% Impedance 100% Voltage</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>% Impedance 100% Voltage</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>% Regulation 100% Full Load</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td>% Regulation 100% Full Load</td>
<td>0.32</td>
<td>0.33</td>
</tr>
<tr>
<td>% Efficiency 100% P.F. Full Load</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>% Efficiency 100% P.F. Full Load</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>% Efficiency 100% P.F. Full Load</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>% Efficiency 100% P.F. Full Load</td>
<td>99.77</td>
<td>99.75</td>
</tr>
<tr>
<td>Total K.W. Resistance in Ohms 100% Voltage (Series Wdg. - Tap &quot;A&quot;)</td>
<td>296</td>
<td>490</td>
</tr>
<tr>
<td>Total K.W. Resistance in Ohms 100% Voltage (Parallel Wdg.)</td>
<td>47.9</td>
<td>47.9</td>
</tr>
<tr>
<td>Total K.W. Resistance in Ohms 100% Voltage</td>
<td>12.3</td>
<td>12.3</td>
</tr>
<tr>
<td>% Impedance 75°C (360000-138000 Volts)</td>
<td>55.9</td>
<td>55.9</td>
</tr>
<tr>
<td>% Impedance 75°C (115000-120000 Volts)</td>
<td>55.9</td>
<td>58.9</td>
</tr>
<tr>
<td>% Impedance 75°C</td>
<td>55.9</td>
<td>55.9</td>
</tr>
</tbody>
</table>

INSULATION TESTS

And to T.V.

| H.V. & L.V. and Core Volts for 1 Min. | 50000 | 50000 |
| H.V. to Core Volts for 1 Min. | 30000 | 30000 |
| Induced Voltage in H.V. Winding Line to Ground | 575000 | 575000 |
| Induced-Direct Current Voltage in H.V. Winding Line to Line | 575000 | 575000 |

<table>
<thead>
<tr>
<th>TEMPERATURE RISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected: 360000-138000 Volts</td>
</tr>
<tr>
<td>Copper Rise Corrected to Shutdown °C</td>
</tr>
<tr>
<td>Oil Rise °C</td>
</tr>
</tbody>
</table>

Unless otherwise specified the above Tests are in accordance with the latest A. S. A. and N. E. M. A. Standards.

Remarks:

Remarks: KVA 77000 102667 128333

T.V. Gradient °C: 10.9 10.5 10.9

* KVA @ 65°C Rise: H.V. and L.V. 330000/440000/550000; T.V. - 56250/71250/10733.
** The Core Loss Value Exceeding Guarantee was submitted to and accepted by the customer.


Age Age 32 for additional test performance data.
<table>
<thead>
<tr>
<th>Z_{ps}</th>
<th>\frac{MVA}{296}</th>
<th>6.21%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z_{pt}</td>
<td>77</td>
<td>55.97%</td>
</tr>
<tr>
<td>Z_{st}</td>
<td>77</td>
<td>42.1%</td>
</tr>
</tbody>
</table>

Note: \( p: 296 \text{ MVA} \)
\( s: 296 \text{ MVA} \)
\( t: 77 \text{ MVA} \)
VA Advantage

Rules of Thumb:
- \( \frac{\text{VA}}{\text{Vm}} \leq 3 \)
- Above 3
  - Leakage, Zsc too high
  - Poor VR
\[ \text{VA advantage} = \frac{\text{VA - Auto}}{\text{VA - 2W}} = \frac{(V_s + V_c) I_H}{V_s I_H} \]

\[ = \frac{V_s + V_c}{V_s} = \frac{V_{H}}{V_x} \]
\[ \sum \text{MMF}_s = 0 \]

\[ = I_s N_s + I_c N_c + I_\Delta N_\Delta \]

\[ \sum \text{VA} = 0 \]

\[ = V_s I_s + V_c I_c + V_\Delta I_\Delta = 0 \]